Geothermal Heat Pump Technology and Green Energy Projects at Richard Stockton College

May 5, 2004



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Richard Stockton College
of New Jersey

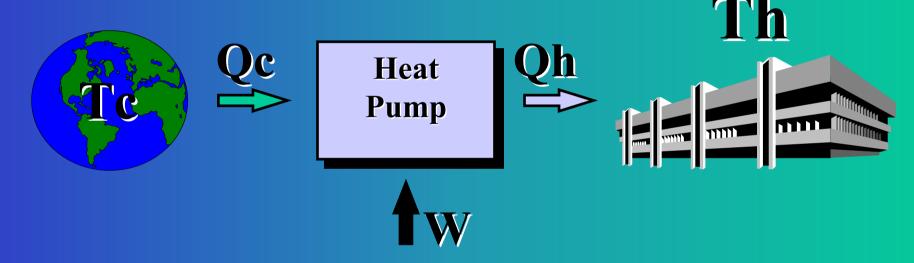
Overview

- Fundamentals of Heat Pumps
- Richard Stockton College
- Financial Analysis of RSC
- CO2 Emission Reduction
- Aquifer Thermal Storage
- Reichtag Project
- Neckersulm Project
- Main Tower
- Road de-icing
- Fuel Cells
- PV
- Wind Power
- Hebrew Academy



Fundamentals of Heat Pumps

Schematic of Energy Flow (Heating)



- Efficiency:
 - Coefficient of Performance = Q_H /W, Q_c /W
 - Energy Efficiency Rating = 3.4 x COP

EXAMPLES OF COP Heating

100,000 BTUH = 30,000 W (30 kW) OF HEATING If Electrical Demand is 7.5 kW, then COP = 30 kW/7.5 kW = 4

22.5 kW of heat coming from Borehole Field7.5 kW from ElectricityFor total of 30kW of heat delivered to Building

EXAMPLES OF COPCooling

100,000 BTUH = 30,000 W (30 kW) OF Cooling

If Electrical Demand is 7.5 kW, then

COP = 30 kW/7.5 kW = 4 (EER = 13)

30 kW of heat coming from Building
7.5 kW from Electricity
For total of 37.5kW of heat into Borehole Field
(ratio of heat into field to out = 37.5/23.5 = 5/3)

Fundamentals of Heat Pumps (con't)

Why use GeoExchange Technology?

- Building Owner's Interest
 - improved indoor environment and safety (no combustion);
 - reduction in operating and maintenance costs;
- Societal Interest
 - more efficient use of energy;
 - emissions reduction;
 - "Green" Technology.

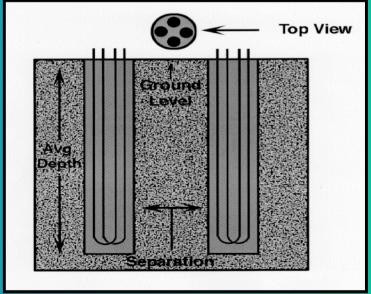


Closed Vertical Loop



Guidelines:

- 100 to 150 ft/ton;
- 15' x 15' spacing
- HDPE Piping



Vertical Piping (1-1/4" SDR-11 HDPE)



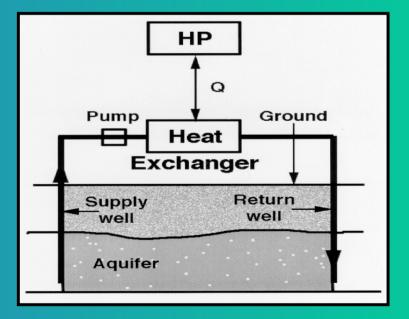


Open Vertical Loop (Ground Discharge)



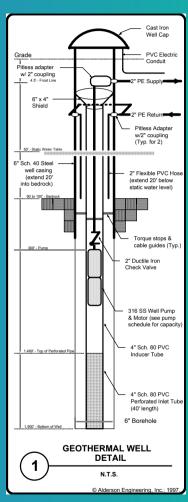
Open Loop Variations:

- pump-and-dump
- use of surface water as a source
- plate-and-frame heat exchanger



Standing Column Well

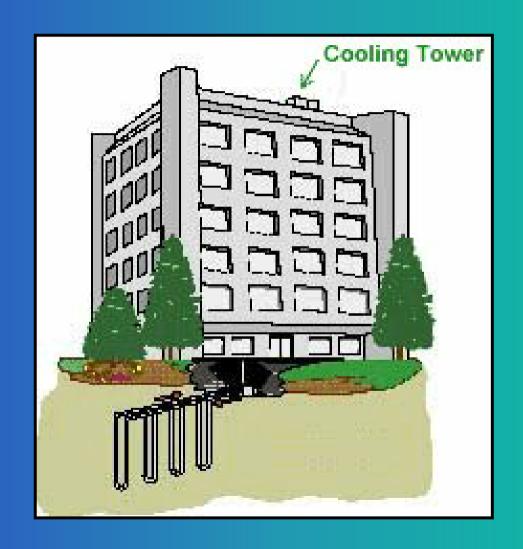




Guidelines:

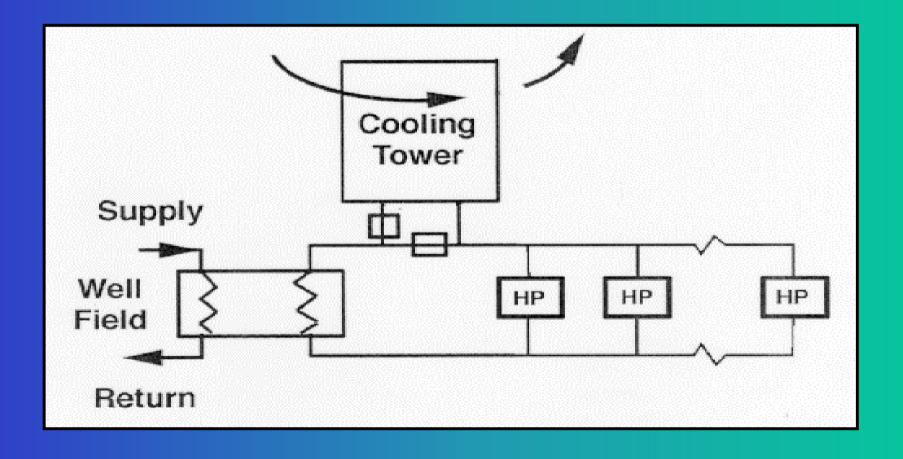
- Concentric pipe-in-pipe (4" / 6");
- Approx. 50 -100 ft/ton;
- Check water quality.

Hybrid Systems



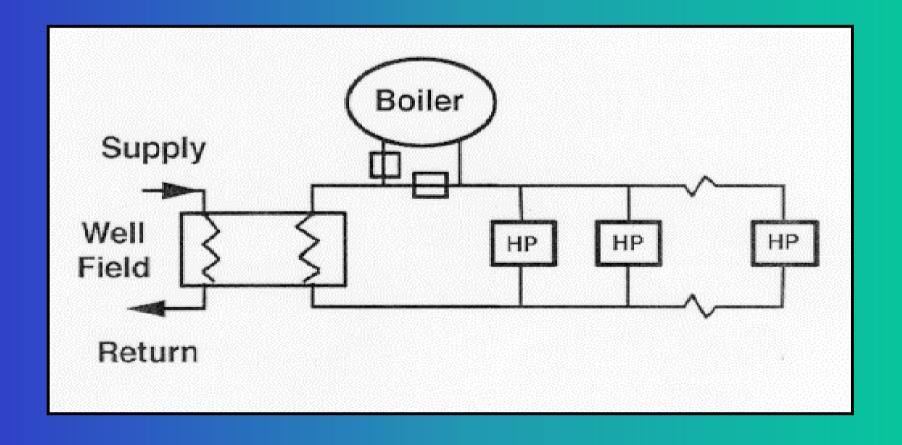
Hybrid Systems (con't)

Hybrid System with Cooling-Tower



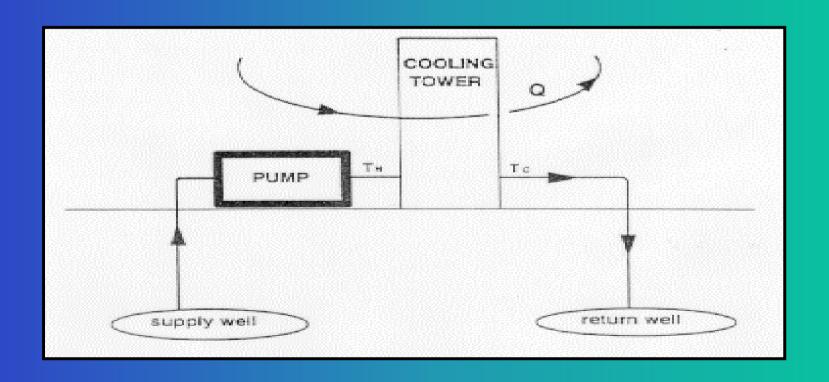
Hybrid Systems

Hybrid System with Boiler



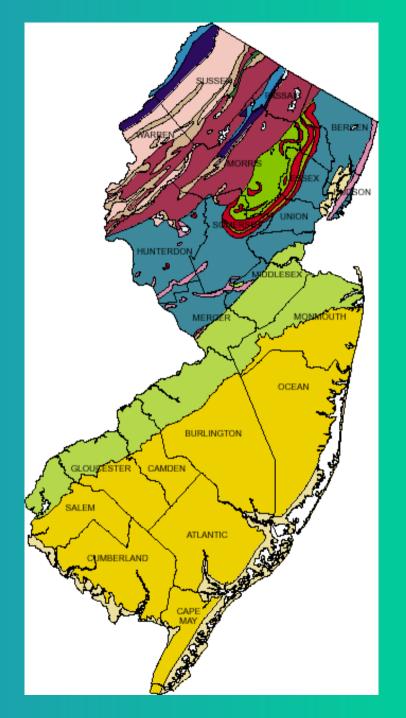
Ground Coupling Technology (con't)

- Coldstore Systems Underground Thermal Energy Storage (UTES)
 - BTES
 - ATES

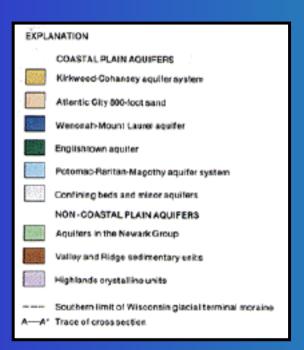


U.S. Geological Survey Map of New Jersey





Principal Aquifers in New Jersey





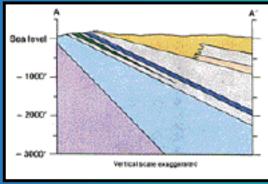
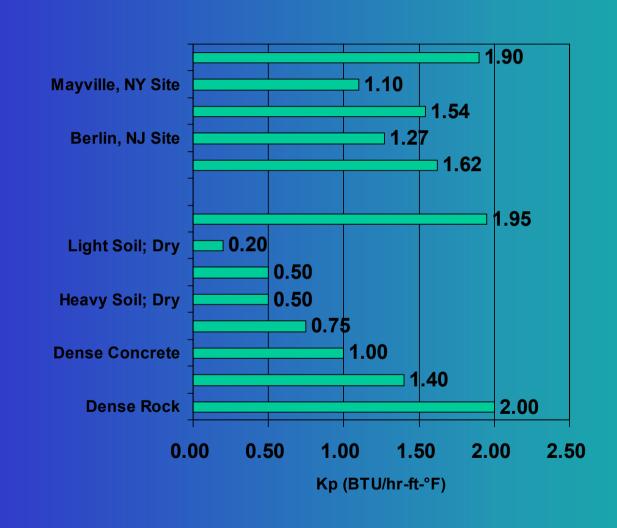


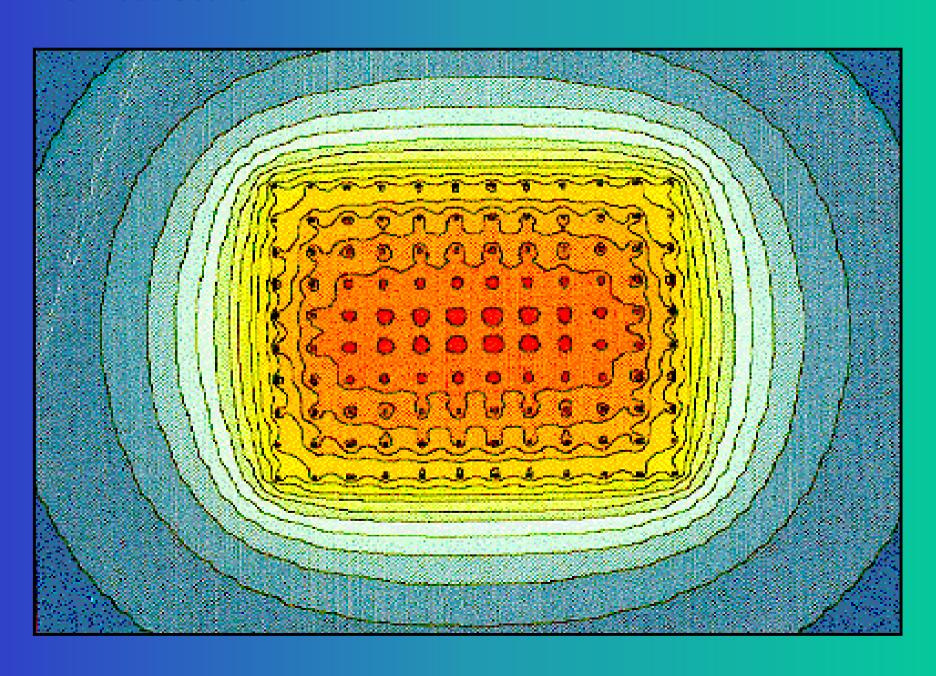
Figure 1. Principal aquifers in New Jersey. 'A, Geographic distribution, 8, Physiographic diagram and divisions. C, Generalized cross section (A-A) of the Coastal Plain. (See table 2 for more detailed description of the aquifers. Sources: A, C, Compiled by O. S. Zapecza from U.S. Beological Survey files. B, Owens and Sohl, 1969; Raisz, 1954.)



Thermal Conductivity of Rock & Soil



- Underground soil/rock formation strongly affects the performance of the well field;
 - Sands and Clays;
 - Rock;
- Affects type of Grouting used.



Case Study:

Richard Stockton College



- Public four-year comprehensive college in Pomona, NJ with 5600 fulltime equivalent students;
- Has largest single well field anywhere;
- gross floor area:
 - 400,000 sq. ft.
- installed heat pump capacity:
 - 1,400 tons (1,620 in 1995)

Richard Stockton College

Borehole Field Data



- Type:
 - vertical, closed-loop w/ central well field
- No. of boreholes:
 - **400**
- Borehole depth:
 - 425 ft.
- Total heat exchanger length:
 - 340,000 ft.
- Borehole length/ton:
 - 121 ft/ton
- Circulating fluid:
 - water
- Flow rate through ground loop:
 - 4,000 gpm (max.)

Vertical Piping Installation



Cost Comparison with Current Rebate With Credits Actual Project W Today's Rebate

HVAC capital cost:

- \$1,627,477 (Premium)
- (\$135,000) (Parking Lot Credit)
- (\$600,000) (Library Addition)
- -(\$300,000) (A&S Bldg Well Field)
- -\$592,477 (Net Premium)
- \$1,100,000 (rebate)

Annual operating cost:

-\$126,047 (Savings)

Simple Payback:

- 4.6 years w/o incentive
- \$507,523 w/incentive

HVAC capital cost:

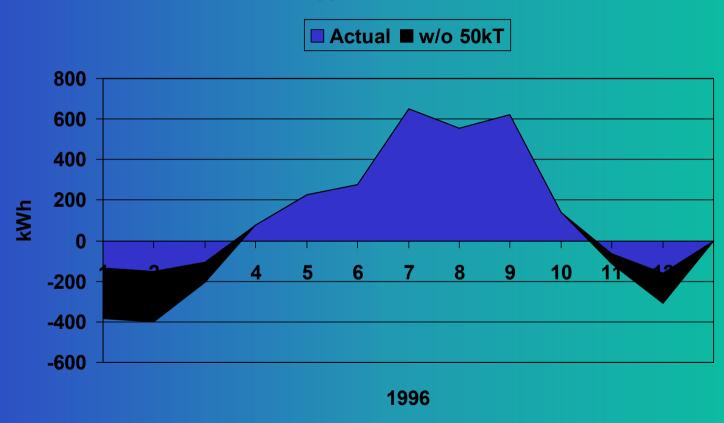
- \$1,627,477 (Premium)
- (\$135,000) (Parking Lot Credit)
- (\$600,000) (Library Addition)
- -(\$300,000) (A&S Bldg Well Field)
- \$592,477 (Net Premium)
- \$200,000 (rebate)
- Annual operating cost:
- -\$126,047 (Savings)

Simple Payback:

- 4.6 years w/o incentive
- 3 years w/incentive

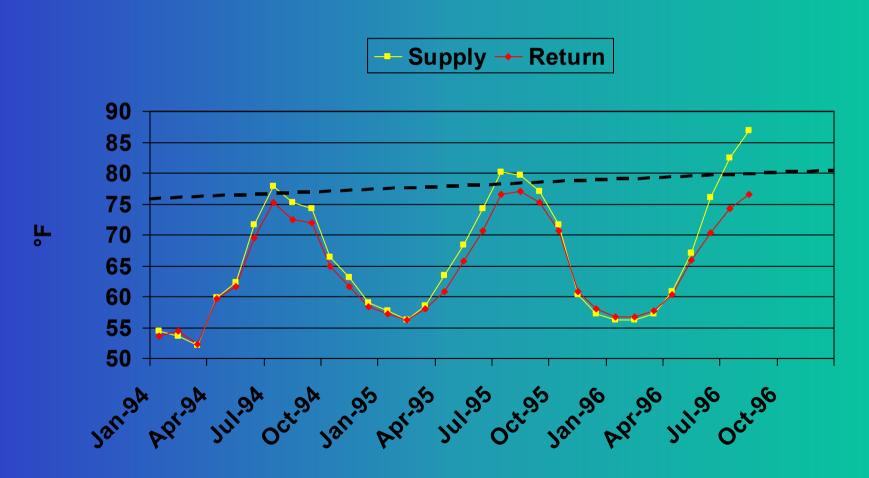
Richard Stockton College Well Field Performance

Thermal Energy into Borehole Field



Borehole Field Performance

Borehole Field Supply & Return Temperatures



Schools and Buildings

- Energy Savings
- CO2 Emission Reductions
 - Cost of Construction

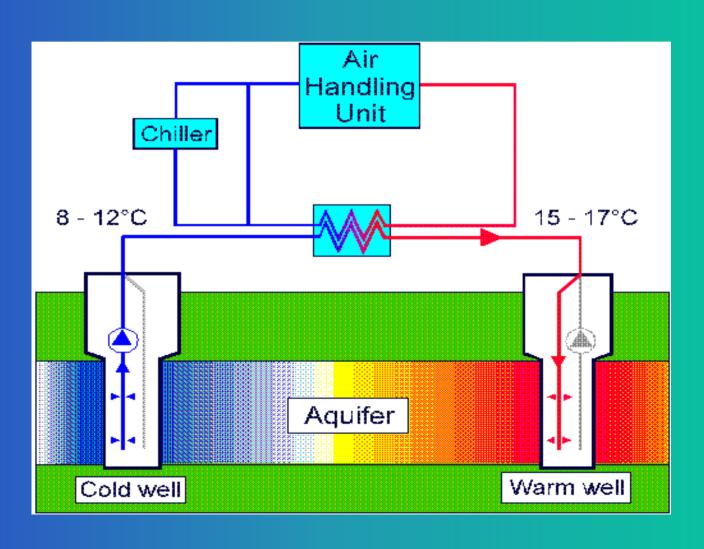
Sample output of AXCESS model for classroom building

	Typical System		Geothermal	Geothermal	
			Medium Efficiency	High Efficiency	
	Gas	Electric	Electric	Electric	
	Therms	kWh	kWh	kWh	
Jan	2,730	60,937	78,095	75,815	
Feb	1,389	65,765	76,457	75,310	
Mar	815	76,615	83,263	82,382	
Apr	478	70,855	72,724	71,759	
May	202	74,663	66,495	63,893	
Jun	0	91,109	78,582	73,283	
Jul	0	122,579	107,517	98,906	
Aug	0	106,210	91,538	84,147	
Sep	165	107,257	95,120	89,540	
Oct	331	88,754	85,017	83,025	
Nov	740	75,522	80,186	79,321	
Dec	2,020	62,408	75,335	73,662	
			990,329	951,043	

Comparison of typical systems with medium and high efficiency GHPs

Project type	`	Cooling Capacity (tons)	CO ₂ reduction	CO ₂ reduction (kg/kW _c)
1 - Commercial office	5600	25	19% - 34%	156-255
2 - Commercial office	160,000	500	41% - 46%	177-201
3a - College cluster housing (10 month occupancy)	23,000	30	38% - 45%	75-91
3b - College cluster housing (12 month occupancy)	23,000	30	43% - 50%	167-198
4 - College classrooms	20,000	75	19% - 26%	63-87
5 - College classrooms	80,000	300	18% - 26%	51-73
6 - College classrooms	25,000	100	17% - 31%	85-159
7 - Middle school (ages 11-13)	140,000	350	29% - 42%	136-192
8 - Elderly care facility	560,000	180	28%-34%	120-144
9 - Single family residence	2000	5.5	48%	220

ATES Cold Storage w Chiller



Efficiencies of Various HVAC Cooling Systems

System	approx. COP
Conventional air-cooled chiller	3
Groundwater-cooled heat pump running as a chiller	5
Open-loop geothermal pump, supply temperature	4
Direct cooling using cold storageincluding electricity consumption for charging the storage (so without reuse of heat)	10 - 20
- excluding electricity consumption for charging the storage	20 - 40

• Overall COP (Coefficient of Performance): amount of thermal energy delivered, divided by the total amount of electricity required.

Cost Comparison Between Chiller and ATES Systems

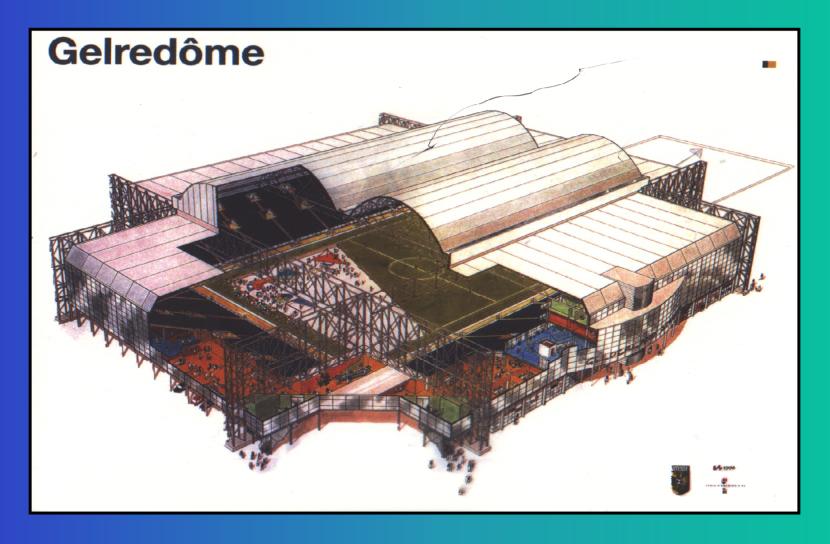
TABLE 1
Investment and Operational Costs in DFi × 1000
(U.S.\$ 1 = DFi 1.97)

	Conventional System	TES System
Air distribution system: not modified	_	_
Additional air outlet channels	_	80
12 air-handling units	570	740
3 chillers and 5 dry coolers incl. piping	1,060	0
Short-term storage incl. piping	0	220
Control system and grid conn. (738/247 kVA)	250	190
Technical room (923/875 m ² [9,940/9,420 ft ²])	820	770
2 wells (depth 100 m [330 ft]) incl. piping	0	310
Engineering and supervision	280	240
Contingencies	150	130
TOTAL INVESTMENT COSTS	3,130	2,680
Additional elec. fans (-/105 MWh)	<u></u> :	19
Elec. chillers and dry coolers (263 MWh)	47	_
Electricity pumps (18/57 MWh)	3	10
Maintenance costs	75	62
	+	+
TOTAL OPERATIONAL COSTS	125	91

Twee Steden Hospital - Tilburg Cold Storage: 330 tons - Operational since 1999



Gelredome Sports Stadium in Arnhem



Gelredome Project

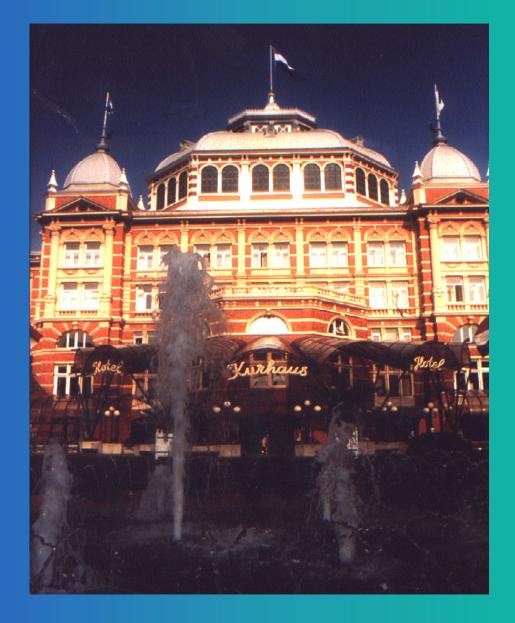
Cooling capacity of heat pump	90 tons
Heating capacity of heat pump	120 tons
Heat production by heat pump	5400 million BTU
Cold-energy production by heat pump	4320 million BTU
Cold-energy demand in summer	1728 million BTU
Cooling capacity of cold storage	800 tons
Groundwater flow rate in winter	270 gpm
Groundwater flow rate in summer	1000 gpm
Pumped quantity in winter	50 million gallons
Pumped quantity in summer	17 million gallons
Injection temperature in winter	45°F
Injection temperature in summer	58°F

Hotel Kurhaus

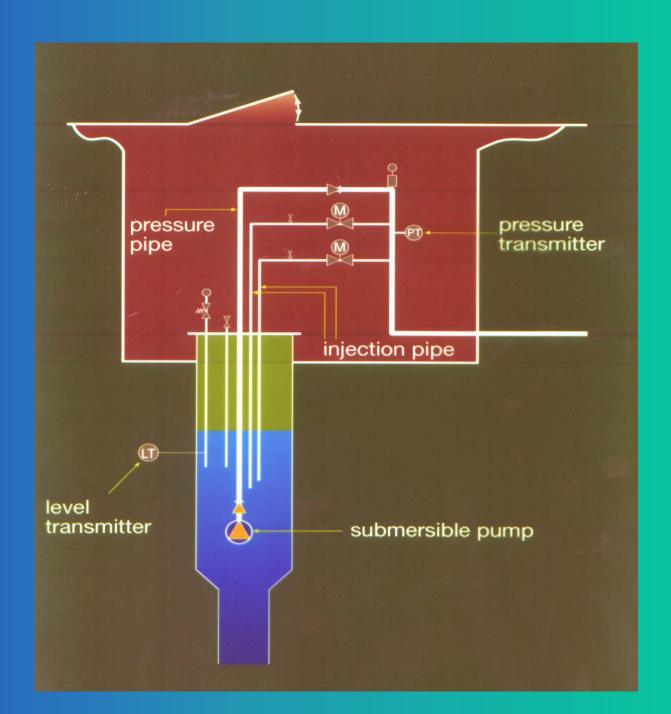
Scheveningen

Cold Storage 70 tons

Operational since 2000



Control and protection



Paleiskwartier



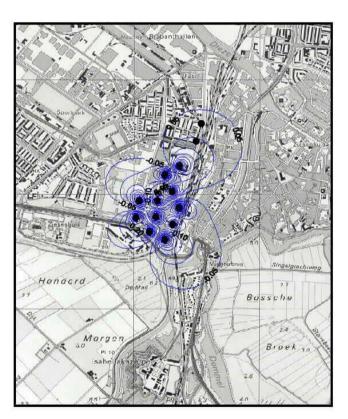


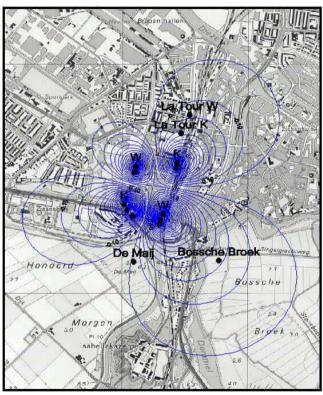


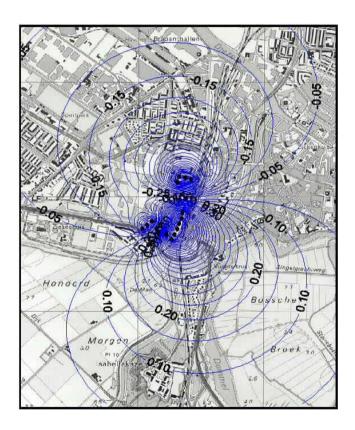
Statistics

- Heat demand: 10 000 MWh_t/a
- Cooling/heating capacity: 1600 tons
- Maximum flow rate: 3300 gpm
- 5 warm wells, 5 cold wells
- Max. amount of water per year: 75 Million gallons

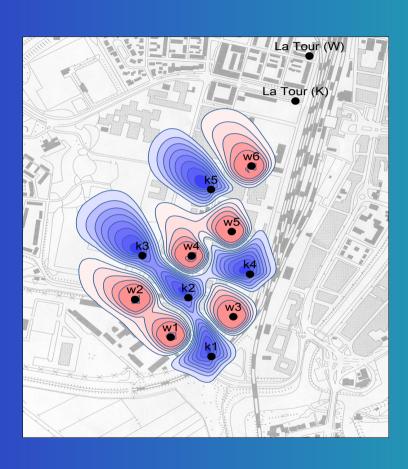
Hydraulic impact



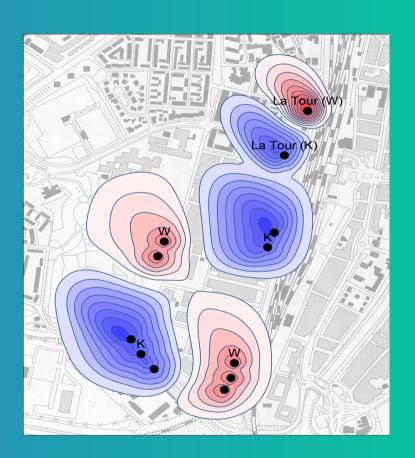




Thermal impact

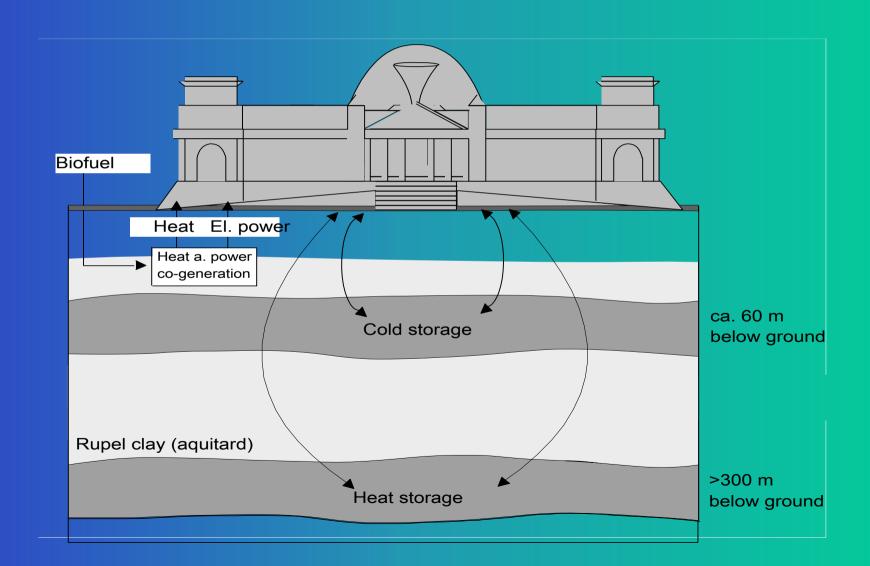




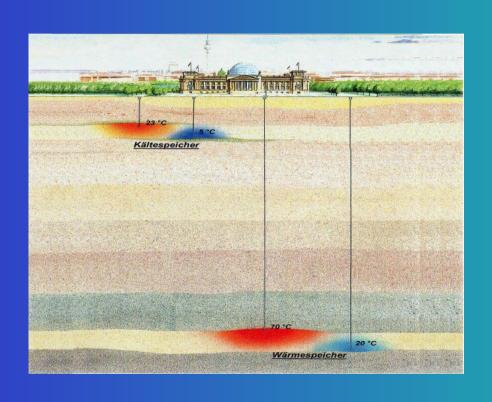


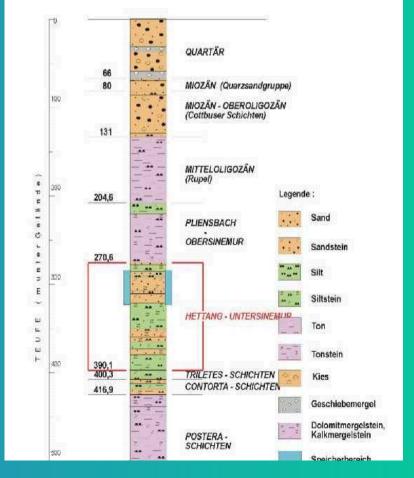
Concept 2

Reichstag Hot and Cold ATES



GEOLOGY OF THERMAL STORE





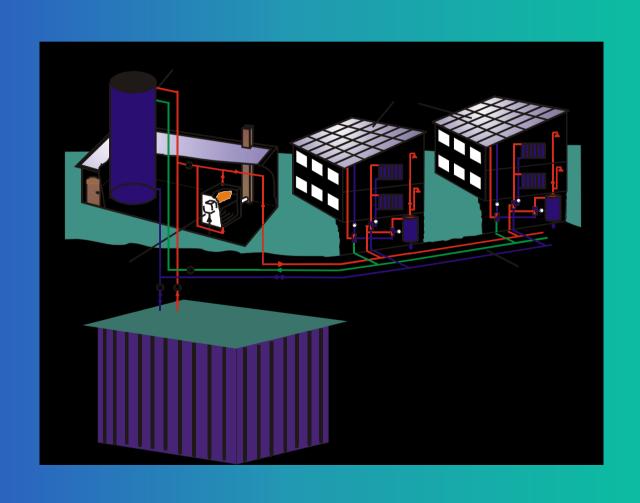
NECKARSULM, GERMANY Overview

- 1300 APARTMENTS BUILDOUT
- 60% HEATING SUPPLIED BY SOLAR
- OPERATED BY PUBLIC UTILITY
- SEVERAL YEARS TO REALIZE HEATING POTENTIAL

NECKARSULM Solar BTES Description

- 168 Boreholes 100 ft deep 6 ft apart
- Volume 740,000 ft³
- Solar Collector Area 30,000 ft²
- Buffer Tank 30,000 gallons
- Final Size Solar Collectors 550,000 ft²
 BTES 5.5 million ft³
- Projected 75-80% heat stored extracted

NECKARSULM, GERMANY BTES SOLAR SYSTEM



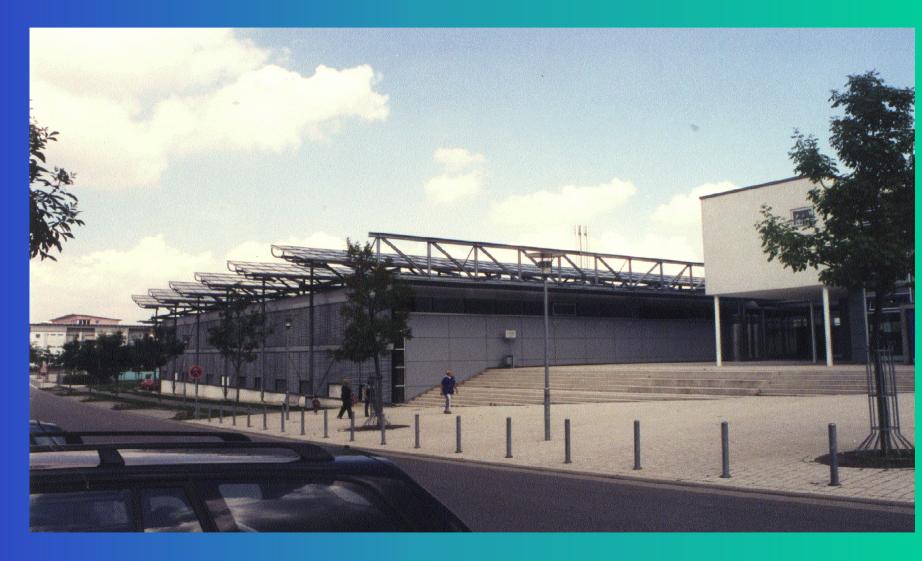
Neckarsulm Housing



Neckarsulm Parking

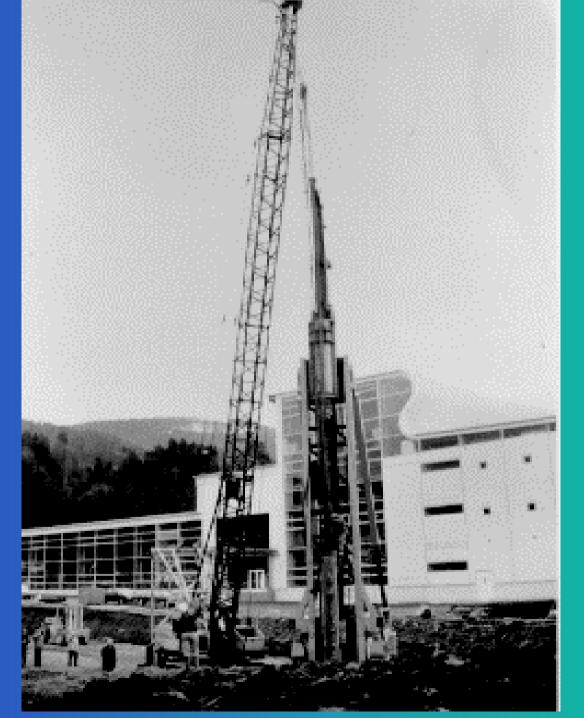


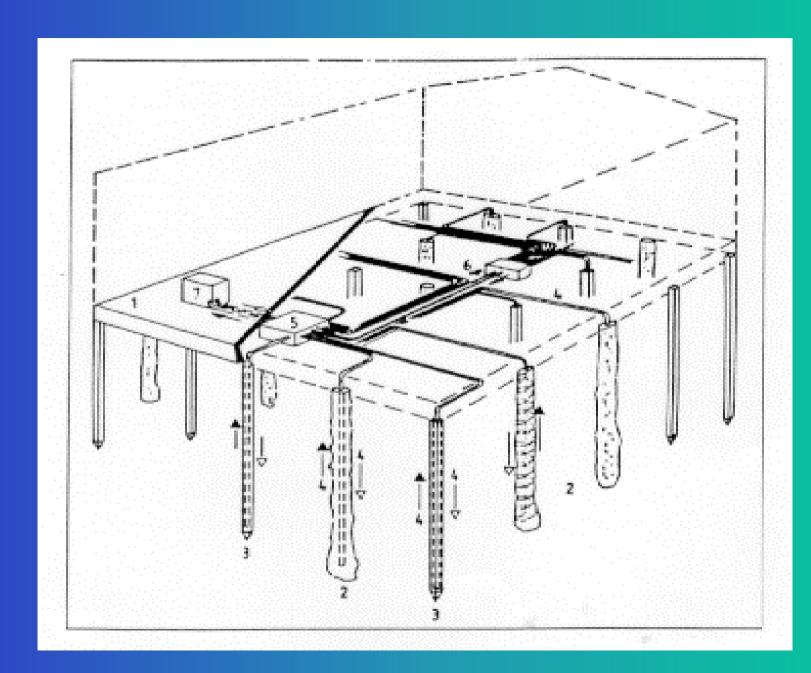
Neckarsulm School



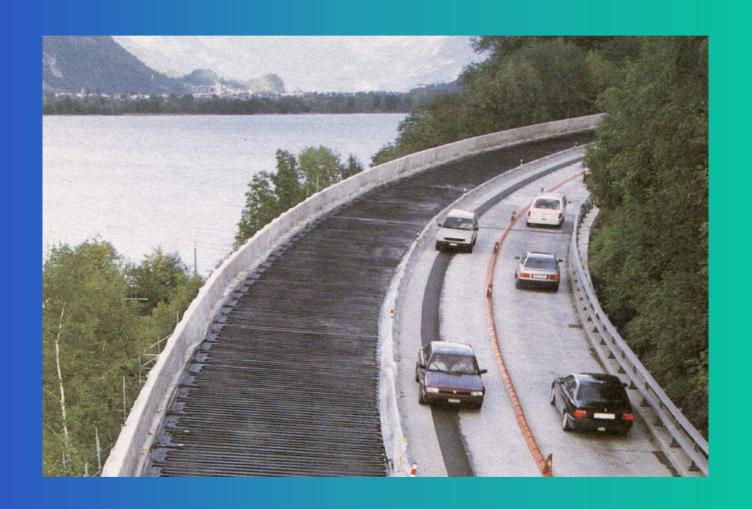
MAIN TOWER FRANKFURT, GERMANY

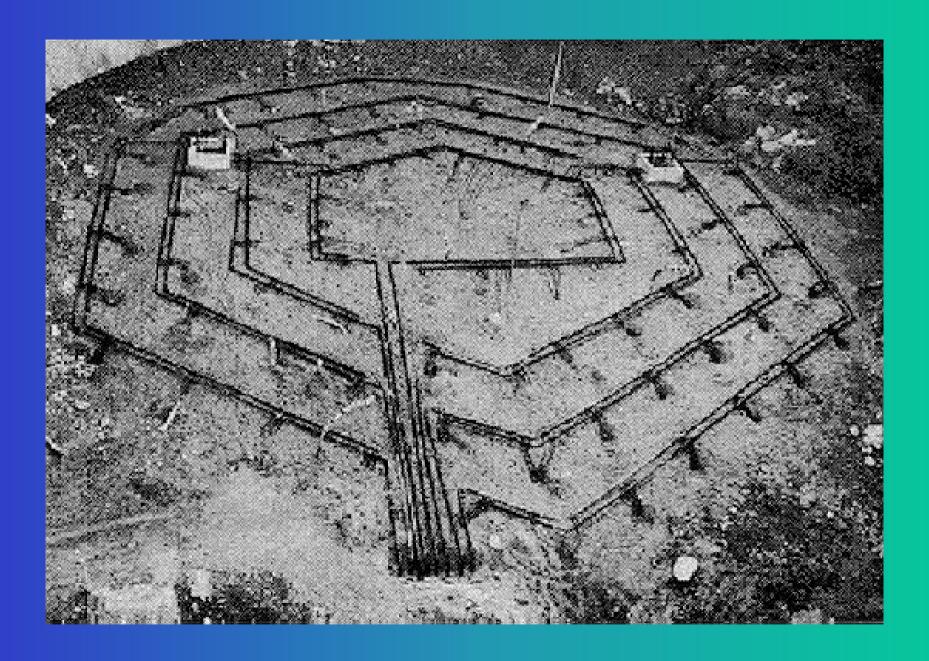
- ENERGY PILES 190 ft deep 125 ft
 3 -5 ft diameter
 50 miles of piping
 260 piles
- DESIGN 20% of Cooling Load
- COLD SOURCES Cooling Tower
 Operated in Winter





BERN, SWITZERLAND SERSO Solar Energy from Road Surface





Solar Photovoltaic

- Very expensive now
- With Current Rebate gives a13-16 yr payback time
- As price comes down will be viable alternative
- Perhaps in five years unless in remote location

Stockton 1995 PV Generation and Value

		Electrical energy		
		kWh gen.	Value	Cost
PV A&S Bldg	18kW	25,000	\$3,000	\$180,000
Whole Comple	360 kW	500,000	\$60,000	\$3,600,000

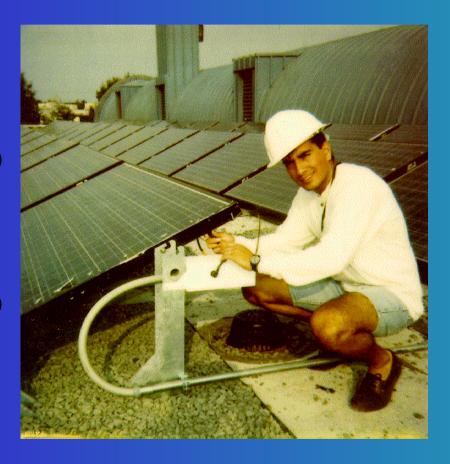
		Cost	rebate	net
PV A&S Bldg		\$180,000	\$90,000	\$90,000
Whole Comple	X	\$3,600,000	\$1,800,000	\$1,800,000

Current SF House PV Generation and Value

	Electrical energy		
	kWh gen.	Value	Cost
10 kW	14,000	\$1,820	\$80,000
	10 kW	kWh gen.	kWh gen. Value

		Cost	rebate	net
Typical SF House		\$80,000	\$56,000	\$24,000
			ROR =	7.6%

Comparison of PV with GHP System on Arts and Sciences Building



Energy Offset per		
	PV	GHP
Electrical (kWh)	25,000	141,000
Gas (Therms)		21,600
Value	\$3,000	\$31,000
Investment	\$180,000	\$320,000
after rebate	\$90,000	\$156,000

Comparison of Tons of CO2 Emission Reduction on A&S Building and Whole Complex



		PV	GHP
PV A&S Bldg		32,250	431,033
Whole Compl	lex	645,000	2,219,600

Fuel Cells

- Generate electricity at about 40% efficiency utilizing natural gas
- Waste heat can be used to heat buildings and hot water
- Overall efficiency can approach 70%
- May be viable in next few years especially in transportation

Stockton Fuel Cell - 200 kW - 900,000 BTUH



Richard Stockton College Fuel Cell

- 200 kW Fuel Cell (Electric)
- Saves about \$100,000 per year in Fuel savings
- Costs \$1,300,000 to install with maintenance contract
- Maintenance is high and Membrane needs to be replaced every five years at a current cost of about \$300,000 assuming 5%/yr degradation
- \$985,000 in rebates for the Stockton project
- Also serves to supply sensitive Science Lab instruments (avoided cost of UPS about \$80,000)

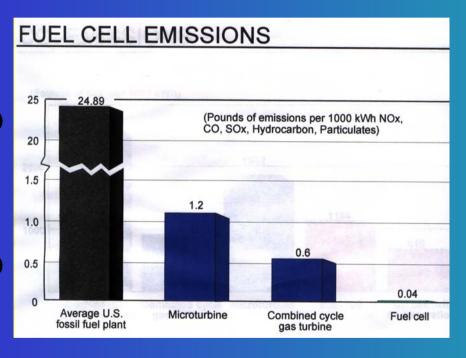
Phosphoric Acid Fuel Cell

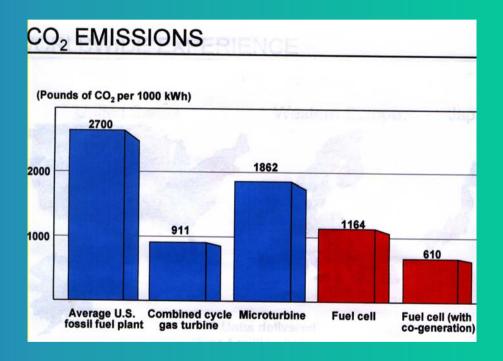


Phosphoric-acid fuel cell (PAFC): The phosphoric-acid fuel cell has potential for use in small stationary power-generation systems. It operates at a higher temperature than PEM fuel cells, so it has a longer warm-up time. This makes it unsuitable for use in cars.

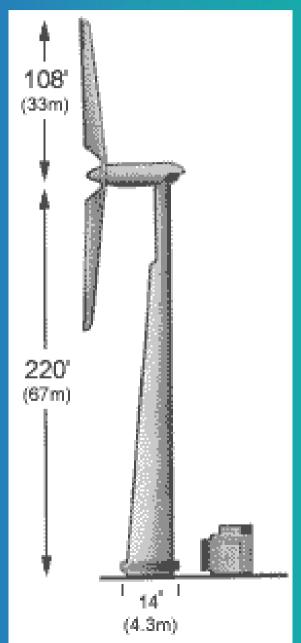
Project Co		
Installation	l	\$1,300,000
Savings		
electric		\$60,000
hot water		55,000
total		\$115,000
Maintenance		\$15,000
Rebates		
NJ Clean E	\$710,000	
UTC/NJHEPS		\$85,000
US DOE		\$200,000
total		\$995,000

Pollution Reduction Benefits





New Wind Generators

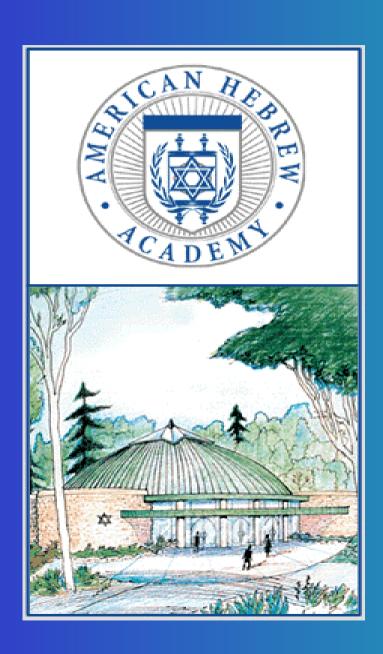


Example of Linear Wind Farm



Q&A





Case Study:

American Hebrew Academy 1225 Jefferson Road Greensboro, N.C. 27410

Contacts:

Mr. Chuck Sabbah (336) 226-1144 Howard Alderson, P.E.

(215) 364-5635

Project Statistics



- Project Type:
 - Non-Profit Preparatory School (Grades 8-12)
- Location:
 - Greensboro, N.C.
- Construction:
 - New (to meet current N.C. energy codes)
- Government/Utility Company Subsidy:
 - None

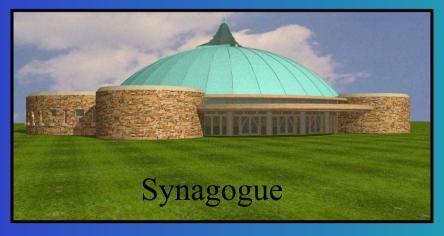
Proposed 100 acre Site Development (Rendering)



Building Styles









Building Styles (cont'd)







